# AVOIDING COSTLY ISSUES IN ESTIMATING AND ENGINEERING UNDERGROUND PRECAST STRUCTURES

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## COURSE TOPICS

- **Estimating and Pricing Overview**
- **Detailed Cost Estimating**
- **Preliminary Design**
- **Codes and Specifications**
- **Sample Specs and Land Mines**
- **Summary**



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## ESTIMATING OVERVIEW

- **Price vs. Cost Estimating vs. Value**
  - Pricing is the process of determining how much you will charge for your product and should be determined by the market.
    - Price is what the customer is willing to pay, all things being equal, and may not be determinative of cost.




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## ESTIMATING OVERVIEW

- **Price vs. Cost Estimating vs. Value**
  - Estimating is the process of determining, within reasonable accuracy, all of the costs associated with manufacturing and delivering the product.



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## ESTIMATING OVERVIEW

- **Price vs. Cost Estimating vs. Value**
  - Value is the perceived worth of purchasing the product from you as opposed to your competitor.



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## ESTIMATING OVERVIEW

- **How to Measure Market Price**
  - Standard or Commodity Products – Septic Tanks, Catch Basins, Manholes, Utility handholes, Etc.
    - Typically Well Established within local markets.
    - Price is per unit or per vertical foot



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## ESTIMATING OVERVIEW

- **How to Measure Market Price**
  - Custom Products – Underground vaults with standard designs.
    - Price per unit with add-ons for accessories

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## ESTIMATING OVERVIEW

- **How to Measure Market Price**
  - Specialty Engineered Structures
    - More difficult to measure due to variables involved with not having a design to work from
    - Look at $/cy as a gut check

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## ESTIMATING OVERVIEW

- **What Determines "Value"**
  - May be Tangible or Intangible
    - Reputation
    - Experience
    - Production Capacity
    - Responsiveness
    - On-Time & Reliable Delivery
    - On-Site Representation


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## ESTIMATING OVERVIEW

- **What Determines "Value"**
  - Quality?
    - Quality is implied – Expectation is to meet plans & specs
    - "Good Quality" or "Exceptional" Quality" are good fluff expressions but hard to measure
    - "Poor Quality" is easier to recognize and can quickly spoil one's reputation and reduce value

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## DETAILED COST ESTIMATE

- **Preparation**
  - To prepare a credible cost estimate for a project you need to start with a clear definition of the scope-of-work
    - How many structures are there?
    - Bid Date
    - Construction Schedule
    - List of Bidders
    - Site constraints that may affect weight limits or accessibility
    - Technical requirements

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## DETAILED COST ESTIMATE

- **Make sure you have enough information**
  - Contract Plans -
    - Site Plan – Showing location of each structure on the site
    - Profiles for drainage and utility structures
    - Project Notes Sheets
    - Detail Sheets

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## DETAILED COST ESTIMATE

- **Make sure you have enough information**
  - Project Specifications
    - Pre-bid meeting notes, RFI's, and Addendums
    - CSI Format
      - Precast Concrete 03 40 xx
  - Geotechnical Report – May not be necessary if soil parameters are outlined in the plans & specs



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## DETAILED COST ESTIMATE

- **Tooling**
  - Forms
    - Existing Mold, Hand-Set, New Formwork
  - Pallets
  - Hole formers & Blockouts
  - Form Ties
  - Form Liners



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## DETAILED COST ESTIMATE

- **Materials**
  - Concrete
  - Reinforcing
  - Misc. Hardware
    - Connections, boots, hatches, castings, etc.
  - Accessories
    - Bar chairs, tie wire, form release, etc.
  - Lifters
  - Coatings
  - Joint Sealant



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## DETAILED COST ESTIMATE

- **Labor**
  - Forming & Set-up
  - Bar Fabrication
  - Pouring, finishing, & stripping
  - Dry Finish
  - Yard Storage
  - Truck Loading
  - Inspection
  - Site representation



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## DETAILED COST ESTIMATE

- **Shipping**
  - Mileage
  - Number of Loads
  - Permits
  - Chase/Escort Vehicles
  - Fuel Surcharge
  - Contract Haulers
  - Tolls



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## DETAILED COST ESTIMATE

- **Engineering**
  - In-House
  - Specialty Consultant
    - NPCA Guide To Hiring A Consultant or Engineer
- QA/QC
- Overhead
  - Ongoing business expenses that support your business but do not generate revenue
  - Admin, management, Utilities, Mortgage, Lease Payment, Depreciation. Taxes, Fees, Insurance



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## PRELIMINARY DESIGN

- What We Need To Know
  - Live Load
  - Additional Specified Loads
  - Depth-of-Bury and Water Table Depth
  - Design Codes



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## PRELIMINARY DESIGN

- Live Load
  - Defined as a dynamic force from occupancy, vehicles, and intended Use.
  - H20, HS20, HS20-44, HS2-+30%Impact
    - These all mean the same thing
    - A-16 – ASTM Designation for HS20 loading
    - AASHTO and ASTM Loads are scalable, i.e. HS25 (A20) is a 25% increase over HS20 (A-16).
      - H10 (A-8) and H15 (A-12) – For light and medium duty traffic



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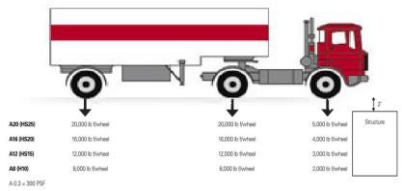
## PRELIMINARY DESIGN



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## PRELIMINARY DESIGN

- Live Load
  - HL93
    - AASHTO Load & Resistance Factor Design
    - Standard Truck or Tandem Axle + Lane Load
      - Standard Truck is the same as HS20
      - Tandem Axles – (2) 25kip axles 4' apart
      - Lane Load = 64psf – No required for spans <15' or for box culverts



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## PRELIMINARY DESIGN

- Live Load
  - Pedestrian
    - ASTM C857 and C890 – 300psf
    - ASCE-7 – Minimum Design Loads and Associated Criteria for Buildings and Other Structures
      - Yards & Terraces, Pedestrian – 100psf
      - Sidewalks, Vehicular Driveways – 250psf
      - Heavy Manufacturing – 250psf



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## PRELIMINARY DESIGN

- Live Load
  - Railroad Loading
    - AREMA – Cooper E80 Locomotive
      - 80,000lbs axles @ 5'oc x 8.5' Tie Width = 1882psf
      - Proximity to Tracks – May determine if load applies to walls only or if it includes the top slab

*Figure 8-2-1. Cooper E 80 (EM 360) Axle Load Diagram*



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## PRELIMINARY DESIGN

- Live Load
  - Aircraft Loads – Can be Vague
    - "Design shall be for 100,000lb aircraft load"
      - What is 100,000lb? Weight of Plane?, Weight of Gear? Wheel Load?
    - FAA provides loads and gear configuration for almost any kind of aircraft



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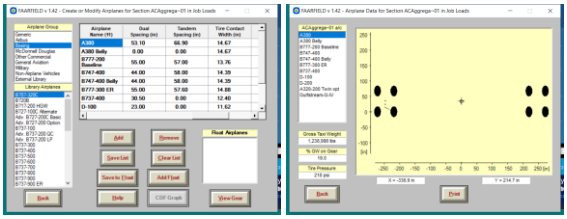



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## PRELIMINARY DESIGN

- Military Loads
  - FM-34.343 "Military Non-Standard Fixed Bridging"
    - Table B-1 – Standard Classes of Hypothetical Vehicles
      - Shows both Track and Wheeled Vehicle Loads

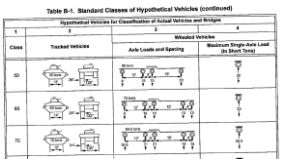

Table B-1. Standard Classes of Hypothetical Vehicles (continued)

Hypothetical Vehicles for Classification of Actual Vehicles and Bridges

| 1 | 2 | 3 | 4 |
|---|---|---|---|
| Class | Tracked Vehicles | Wheeled Vehicles: Axle Loads and Spacing | Wheeled Vehicles: Maximum Single-Axle Load (in Short Tons) |
| 30 | | | |
| 60 | | | |
| 70 | | | |



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## PRELIMINARY DESIGN

- Live Load
  - Heavy Construction or Port Loading Equipment
    - Requires a spec sheet showing axle loads and spacing



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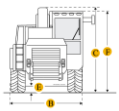
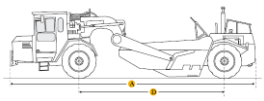
**Caterpillar 637E Motor Scraper**





Dimensions

| Dimensions | |
|---|---|
| A Overall Length | 46.84 ft in |
| B Overall Width | 12.92 ft in |
| C Overall Height | 14.08 ft in |
| D Wheelbase | 28.78 ft in |

Weights

| | |
|---|---|
| Total Operating - Empty | 112089 lb |
| Front Axle - Empty | 66182.1 % |
| Rear Axle - Empty | 45957.6 % |
| Total Operating - Loaded | 181091 lb |
| Front Axle - Loaded | 91674.0 lb |
| Rear Axle - Loaded | 89417.1 % |



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## PRELIMINARY DESIGN

- Additional Specified Loads
  - Pulling Irons
  - Surcharge from Adjacent Building
  - Sluice Gate Actuators
  - Thrust Loads
  - Seismic Forces



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## PRELIMINARY DESIGN

- Depth of Bury and Water Table
  - Lateral Loads increase with depth below the surface
    - EP(h) = Effective Horizontal Earth Pressure
    - Active Soil Pressure – Walls can yield due to rotation or defelction
    - At-Rest Soil Pressure – Walls cannot yield



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## PRELIMINARY DESIGN

- Depth of Bury and Water Table
  - EP(h) = Effective Horizontal Earth Pressure, Active
    - Above Water Table: EP(h) = $K_a$ x $W_S$
      - $K_a$ = Coefficient of Active Soil Pressure
      - $W_S$ = Unit Weight of Soil
    - Example: EP(h) = 0.33 x 120pcf = 39.6psf/ft



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## PRELIMINARY DESIGN

- Depth of Bury and Water Table
  - EP(h) = Effective Horizontal Earth Pressure, Active
    - Below Water Table: EP(h) = $K_a$ x ($W_S$ – $W_w$) + $W_w$
      - $K_a$ = Coefficient of Active Soil Pressure
      - $W_S$ = Unit Weight of Soil
      - $W_w$ = Unit Weight of Water
    - Example: EP(h) = 0.33 x (120pcf – 62.4pcf) + 62.4pcf = 81.4psf/ft



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## PRELIMINARY DESIGN

- Depth of Bury and Water Table
  - EP(h) = Effective Horizontal Earth Pressure, At-Rest
    - Above Water Table: EP(h) = $K_o$ x $W_S$
      - $K_o$ = Coefficient of Active Soil Pressure
      - $W_S$ = Unit Weight of Soil
    - Example: EP(h) = 0.50 x 120pcf = 60.0psf/ft



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## PRELIMINARY DESIGN

- Depth of Bury and Water Table
  - EP(h) = Effective Horizontal Earth Pressure, At-Rest
    - Below Water Table: EP(h) = $K_o$ x ($W_S$ – $W_w$) + $W_w$
      - $K_o$ = Coefficient of Active Soil Pressure
      - $W_S$ = Unit Weight of Soil
      - $W_w$ = Unit Weight of Water
    - Example: EP(h) = 0.50 x (120pcf – 62.4pcf) + 62.4pcf = 91.2psf/ft



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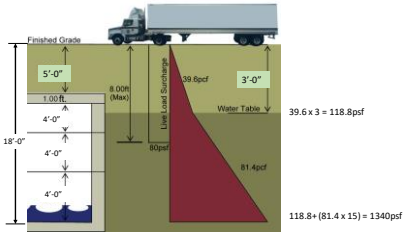
## PRELIMINARY DESIGN



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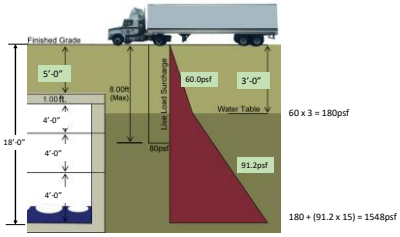
## PRELIMINARY DESIGN



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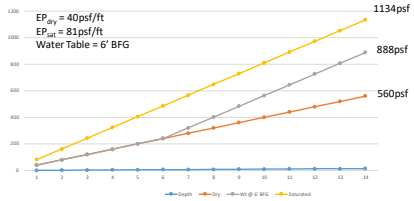
## EFFECT OF WATER TABLE ON LATERAL EARTH LOADS



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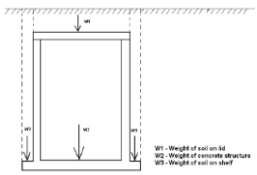
## PRELIMINARY DESIGN




- Buoyancy Provisions
  - Water Table Depth
  - Factor-of-Safety



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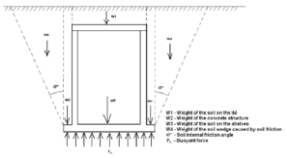
## PRELIMINARY DESIGN



- Buoyancy Provisions
  - Water Table Depth
  - Factor-of-Safety
  - Soil Wedge



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## DESIGN CODES AND SPECIFICATIONS

- **ASTM**
  - **C857 & C858 – Utility Structures**
  - **C890 & C913 – Water & Wastewater Structures**
  - **C478 – Round Manholes**
  - **C1227 – Septic Tanks**
  - **C1613 – Grease Interceptor Tanks**
  - **C1889 – Rectangular Vaults Using LRFD**



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## DESIGN CODES AND SPECIFICATIONS

- **ACI – American Concrete Institute**
  - **ACI 318 – "Building Code Requirements for Structural Concrete"**
  - **ACI 350 "Code Requirements for Environmental Engineering Concrete Structures"**
  - **ACI 440 "Guide for the Design and Construction of Structural Concrete Reinforced with Fiber-Reinfoced Polymer (FRP) Bars"**
- **"Code" Means that it is written as a legal document**
- **"Guide" Means written for guidance only**



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## DESIGN CODES AND SPECIFICATIONS

- AASHTO – American Association of Safety and Highway Transportation Officials"
  - AASHTO "LRFD Bridge Design Specification"
  - 9th Edition is most current
  - HL-93



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## DESIGN CODES AND SPECIFICATIONS

- FAA - Federal Aviation Administration
  - AC 150/5370-10H "Standard Specifications for Construction of Airports"
    - P-610 Concrete for Miscellaneous Structures
    - D-751 Manholes, Catch Basins, Inlets, and Inspection Holes
    - D-752 Concrete Culverts, Headwalls and Miscellaneous Drainage Structures
    - L-115 Electrical Manholes and Junction Structures



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## DESIGN CODES AND SPECIFICATIONS

- FAA - Federal Aviation Administration
  - AC 150/5320-6F "Airport Pavement Design and Evaluation"
    - Appendix B. "Design of Structures"



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## DESIGN CODES AND SPECIFICATIONS

- Other Codes & Specs
  - IAPMO/ANSI Z1000 – "Prefabricated Septic Tanks"
  - NFPA-22 – "Water Tanks for Fire Protection"
  - ASCE-7 "Minimum Design Loads and Associated Crieria for Buildings and Other Structures"
  - AREMA – "Manual for Railway Engineering"



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## DESIGN CODES AND SPECIFICATIONS

- Other Codes & Specs
  - State DOT Specifications & Standards
  - FHWA – Federal Highway Adminstration
  - CSA – Canadian Standards Association
  -



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## PRELIMINARY DESIGN

- What We Know
  - Live Load
  - Additional Specified Loads
  - Depth-of-Bury and Water Table Depth
  - Design Codes
- What do we do now?



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## PRELIMINARY DESIGN

- What do we do now?
  - Look for previous design using same parameters
  - Get help from specialty engineer
  - Use preliminary design software
  - Use working stress design guide



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## SAMPLE CALCS & LAND MINES

STRUCTURAL NOTES

1. CONCRETE: 28 DAY COMPRESSIVE STRENGTH OF 7,000 PSI.
2. REBAR: ASTM A-615 GRADE 60
3. MESH: ASTM A-185 GRADE 65
4. DESIGN: ACI-318-05 BUILDING CODE
5. LOADS: 120.00 kip
   ASTM C-857 "MINIMUM STRUCTURAL DESIGN LOADING FOR UNDERGROUND PRECAST CONCRETE UTILITY STRUCTURES"
   30% IMPACT FOR LESS THAN 2'-0" SOIL COVER
   SOIL DENSITY 120 pcf
   40 pcf E.F.P. LATERAL SOIL PRESSURE ABOVE WATERTABLE
   80 pcf E.F.P. LATERAL SOIL PRESSURE BELOW WATERTABLE
   80 psf LIVE LOAD SURCHARGE
   NO LIVE LOAD SURCHARGE FOR SOIL COVER < 8'-0"
   TOP OF VAULT 5'-0" BELOW FINISHED GRADE (MAXIMUM)
   WATERTABLE 5'-0" BELOW FINISHED GRADE (ASSUMED)
   REQUIRES 8,000 PSF MINIMUM ALLOWABLE SOIL BEARING PRESSURE



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## SAMPLE CALCS & LAND MINES

DESIGN SPECIFICATIONS

THIS STRUCTURE CONFORMS TO "STANDARD SPECIFICATIONS FOR HIGHWAY BRIDGES" ADOPTED BY THE AMERICAN ASSOCIATION OF STATE HIGHWAY AND TRANSPORTATION OFFICIALS, 2002; ACI-350 FOR ENVIRONMENTAL ENGINEERING CONCRETE STRUCTURES AND THE 2004 IDOT BRIDGE DESIGN MANUAL.

DESIGN LOAD

HS25 AND THE ALTERNATE MILITARY DESIGN
FUTURE WEARING SURFACE OF 60 LBS/SQ FT

DESIGN DATA

CONCRETE CLASS S – COMPRESSIVE STRENGTH 4.5 KSI
(ALL CAST-IN-PLACE CONCRETE)

REINFORCING STEEL – ASTM A615 OR A996, GRADE 60, MINIMUM
YIELD STRENGTH 60 KSI

STRUCTURAL STEEL – STAINLESS STEEL SERIES 316
– ASTM A709 GRADE 50

REINFORCING STEEL

ALL REINFORCING STEEL SHALL BE EPOXY COATED.



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## SAMPLE CALCS & LAND MINES

B. The vault chamber or structure shall be designed for the following loads and possible combinations thereof:
   1. Lateral soil pressure = 60 PCF (H), where H is the height from grade, as shown on the Drawings, to the point of the structure being considered.
   2. Soil weight shall be assumed to be 120 PCF.
   3. AASHTO HS-20-44 loading.
   4. Weight of precast concrete structure.
   5. Initial handling and erection loadings, including design of galvanized lifting hooks using a safety factor = 4.0.

C. Investigate buoyancy and soil bearing considerations for groundwater elevation shown. The groundwater shall be assumed to be at the ground surface, unless otherwise noted on the drawings.



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## SAMPLE CALCS & LAND MINES

C. WATER EXFILTRATION TEST:

1. After the manhole has been assembled in place, all lifting holes shall be filled and pointed with an approved non-shrinking mortar. All pipes and other openings into the manhole shall be suitably plugged and the plugs braced to prevent blow out. The test shall be made prior to placing the shelf and invert. If the groundwater table has been allowed to rise above the bottom of the manhole, it shall be lowered for the duration of the test.

2. The manhole shall be filled with water to the top of the cone section. If the excavation has not been backfilled and observation indicates no visible leakage, that is, no water visibly moving down the surface of the manhole, the manhole may be considered to be satisfactorily water-tight. If the test, as described above, is unsatisfactory as determined by the Engineer or if the manhole excavation has been backfilled, the test shall be continued. A period of time may be permitted if the Contractor so wishes, to allow for absorption by the manhole. At the end of this period, the manhole shall be refilled to the top of the cone, if necessary, and a measuring time of at least 8 hours begun. At the end of the test period, the manhole shall be refilled to the top of the cone, measuring the volume of water added. This amount shall be extrapolated to a 24-hour loss rate and the leakage determined on the basis of



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## SAMPLE CALCS & LAND MINES

DESIGN CRITERIA:

1. LIVE LOAD = AASHTO HS-25
2. DEAD LOAD = DRY EARTH SURCHARGE PER AASHTO REQUIREMENTS
3. WATERTABLE = 3'-0"
4. CONCRETE = 5000 PSI
5. REBAR = ASTM 615 GRADE 60 STEEL
6. DEPTH FROM GRADE TO TOP OF MANHOLE ROOF VARIES FROM 3 TO 5 FEET
7. PULLING EYE LOAD TENSION AND SHEAR = 45 KIPS EACH

DESIGN SPECIFICATIONS:

1. ACI-318 "BUILDING CODE REQUIREMENTS FOR STRUCTURE CONCRETE", LATEST EDITION.
2. AASHTO "LRFD BRIDGE DESIGN SPECIFICATION", LATEST EDITION.
3. AISC STEEL CONSTRUCTION MANUAL, LATEST EDITION.
4. ASTM C858 "STANDARD SPECIFICATIONS FOR UNDERGROUND PRECAST CONCRETE UTILITY STRUCTURES", LATEST EDITION.
5. ASTM C478 "STANDARD SPECIFICATIONS FOR PRECAST REINFORCED CONCRETE MANHOLE SECTIONS", LATEST EDITION.



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## SAMPLE CALCS & LAND MINES

DRAINAGE NOTES:

1. HEAVY LOAD RATED DRAINAGE STRUCTURE SHALL BE PRECAST, DESIGN STRUCTURE FOR 113,300 POUND WHEEL LOAD WITH 140 PSI TIRE PRESSURE. PROVIDE SEALED SHOP DRAWINGS FOR PRECAST.
2. SUPPLIER/CONTRACTOR TO VERIFY PLAN DIMENSIONS WITH GRATE MANUFACTURER.
3. PROVIDE WATERTIGHT CONNECTION TO ALL CONNECTED PIPES.



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## SAMPLE CALCS & LAND MINES

1.4 DESIGN REQUIREMENTS

A. All precast units shall be constructed with ship lap joints and of shapes and sizes as shown on the Drawings.

B. Structural design calculations shall include the following loading conditions:
1. Empty precast structure with all external loads at maximum groundwater elevation
2. Precast structure full of liquid with no backfill (leak test condition for tanks)
3. Lifting of precast units. Member design shall consider forces and distortions during curing, stripping, storage, transportation, and erection so that precast members are not overstressed or otherwise damaged.

C. All base sections shall be designed with the floor slabs cast as an integral placement with the bottom wall section.

D. Minimum 28 day compressive strength: f'c = 5,000 psi.

E. Reinforcing Steel
1. ASTM A615/A615M grade 60 deformed bars or ASTM A1064/A1064M welded wire fabric.
2. Minimum reinforcing steel in all concrete sections shall be no less than 0.003 times the gross area of the concrete section.

F. Concrete cover on reinforcing steel: 1½ inches minimum.

G. The interior dimensions of the precast concrete structures shall be as shown on the Drawings. Walls, top slabs and base slabs shall be a minimum of 8" thick.

H. The precast concrete structure shall be designed to support its own weight plus the following minimum superimposed vertical and lateral loads:
1. Live load on top slab – 300 psf.
2. Lateral soil pressure - 95 pcf/vf. The top of the pressure diagram shall be assumed to originate at finish grade as shown on the drawings.
3. Uniform live load lateral surcharge of 125 psf applied horizontally to the sides of the precast structure for a depth of 10 feet below finish grade.
4. Interior liquid loading (tanks) – Design for the tank to be filled to the top with no backfill in place. Liquid density shall be assumed to be 63 pcf/vf.
5. Except where higher loads are specified herein, wastewater structures shall be designed for the minimum loads prescribed in ASTM C890.

I. The precast concrete structure shall be designed to resist flotation:
1. A factor of safety of 1.15 shall be used against flotation based on weights of empty structure and soil directly over footing extensions and above the top slab (if any).
2. Unless otherwise indicated on the Structural Drawings, the maximum groundwater level shall be assumed to be at finished grade.
3. The base slab may be extended beyond the face of the wall to provide additional resistance to flotation.
4. Unless otherwise indicated on the Drawings, additional cast-in-place concrete base slabs will not be permitted for flotation resistance.
5. Frictional resistance shall not be permitted.

03420-4
PRECAST CONCRETE STRUCTURES



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## SUMMARY

- **Know your market and quote prices accordingly**
- **Use a sanity check to determine of your price makes sense**
- **Look for "Land Mines" within plans and specs. If there is a provision you do not understand, ask for help**
- **Use preliminary design programs – but be cautious**
- **Build your library of codes and standards – Many are available on-line**



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## AVOIDING COSTLY ISSUES IN ESTIMATING AND ENGINEERING UNDERGROUND PRECAST STRUCTURES

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